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13. ABSTRACT *(Maximum 200 words)*

The main goal of this objective is to use coupled ocean-ice numerical models to study the basin scale ocean circulation and ocean-ice interaction in the Okhotsk Sea, and to examine important processes that maintain the unique oceanographic setting, such as the ODTL in this large marginal sea. We use a hierarchy of models, from a basin-averaged column model of ocean-ice interactions (Yang and Honjo, 1996) to a 3-D primitive equation ocean general circulation models coupled with a dynamical and thermodynamical sea-ice model. Meanwhile, we have analyzed some unpublished in situ observations (mainly hydrography records from the Japanese Hydrography Office), satellite SSM/I data of sea-ice concentration, and meteorological observations (from Comprehensive Ocean and Atmosphere Data Sets (COADS) and from the Japan Meteorology Agency) to examine ocean-ice interactions and mechanisms for interannual variations.

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Final Report

Grant No. N00014-96-1-0463

Title: Modeling the wind and buoyancy driven circulation and ice interaction in the Okhotsk Sea

Principal Investigator: Jiayan Yang

Abstract

The Sea of Okhotsk is one of the largest semi-enclosed marginal sea, connected with the North Pacific Ocean through numerous Kuril straits, and with the Sea of Japan (the East Sea) through Soya Strait. Despite its moderate geographic location, the Sea of Okhotsk is mostly covered by sea ice in winter. The sea surface temperature in summer, however, reaches about 15°C. This strong seasonal variation gives rise to some important physical oceanography features, such as the Okhotsk Sea Dichothermal Layer (ODTL) (a near-freazing subsurface layer that exists through the whole year) and the formation of the North Pacific Intermediate Water. Meanwhile, satellite observation shows that interannual variation of sea-ice extent is among the greatest in the world. The main objective is to use coupled ocean-ice numerical models to study the basin scale ocean circulation and ocean-ice interaction in the Okhotsk Sea, and to examine important processes that maintain the unique oceanographic setting, such as the ODTL in this large marginal sea. We use a hierarchy of models, from a basin-averaged column model of ocean-ice interactions (Yang and Honjo, 1996) to a 3-D primitive equation ocean general circulation models coupled with a dynamical and thermodynamical sea-ice model. Meanwhile, we have analyzed some unpublished in situ observations (mainly hydrography records from the Japanese Hydrography Office), satellite SSM/I data of sea-ice concentration, and meteorological observations (from Comprehensive Ocean and Atmosphere Data Sets (COADS) and from the Japan Meteorology Agency) to examine ocean-ice interactions and mechanisms for interannual variations.

Summary

We have developed a basin-averaged coupled ocean-ice model to study the formation and variation of the ODTL and sea-ice cover. The results show that the water Okhotsk Dichothermal Layer is renewed by winter convective mixing when brine rejection associated with sea-ice formation destabilizes the water column. In the summer, the low salinity (due to spring melting of sea ice) and high temperature water in the mixed layer prevents the vertical mixing to reach the dichothermal layer, and therefore, the near freezing layer is able to sustain. Our study also shows that the seemingly net-zero-gain process of winter freezing and summer melting can result in interannual variations in the ODTL and in sea-ice extent. Our study indicates that the strong seasonal variation in the atmosphere forcing fields is primarily responsible to some of the unique observed features in the Okhotsk Sea, such the the existence of the near freezing ODTL. We used this model to study the effects of inflows from Sea of Japan through Soya Strait and from the North Pacific Ocean through Kurile Straits on the mean hydrographic structure and ODTL variability. The role of fresh water flux from Amur River runoff and surface evaporation-precipitation is also investigated. The result was published in *Journal of Geophysical Research* in 1996.

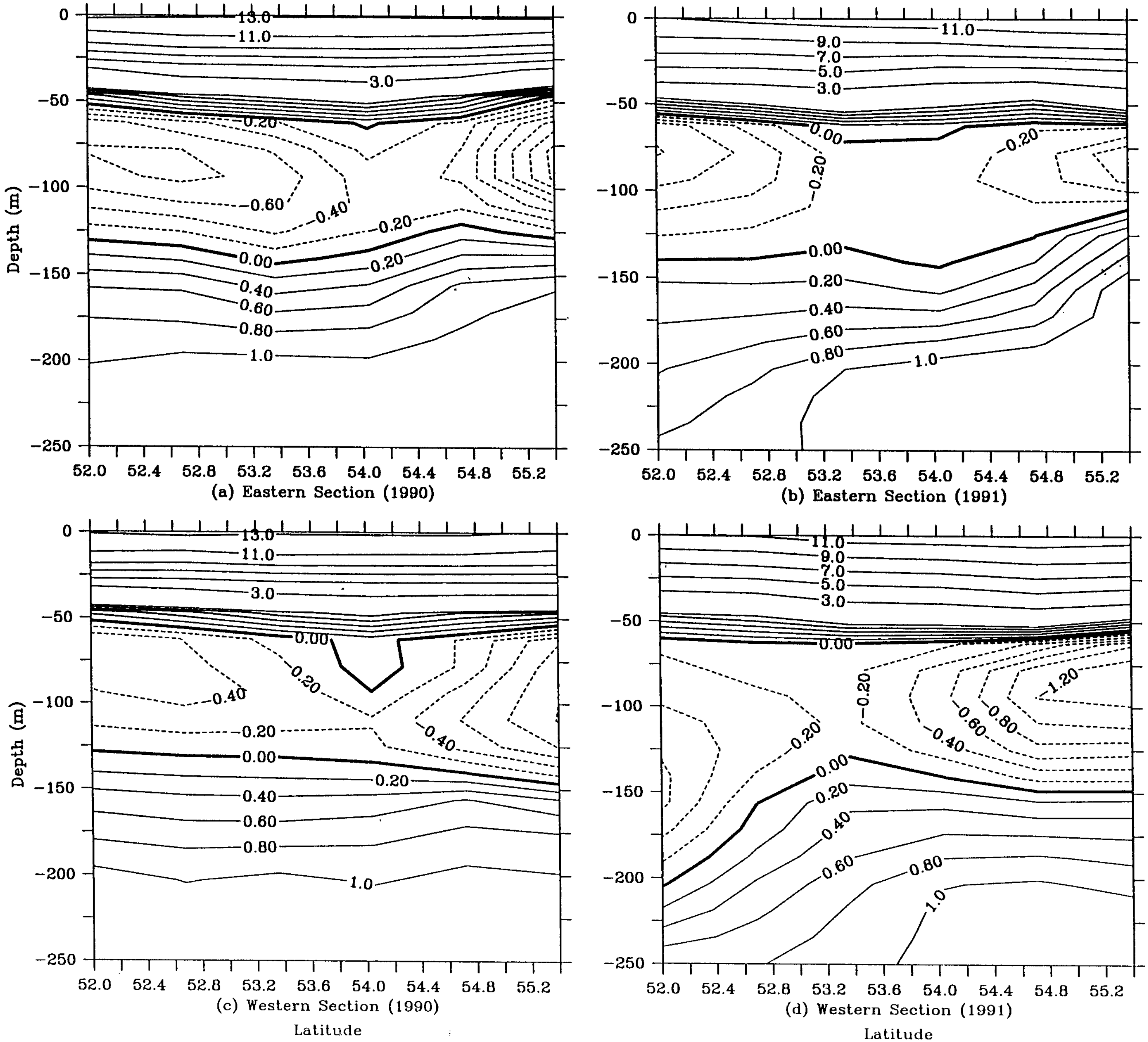
We have extended our study to using a 3-D model so that key processes can be examined in a more realistical setting. We use this model to study the mean circulation and spatial variations of sea-ice extent. We are focused on modeling the seasonal cycle but will extend to include interannual variations. Dr. S. Honjo and I have been working on some newly available hydrography and geochemical tracer data (unpublished previously) collected by R/V Shoyo (Shoyo cruise 9007 and 9105) of the Hydrography Office of Japan during August, 1990 and 1991. Significant changes in potential temperature, salinity and dissolved oxygen content were observed between 1990 and 1991. We therefore analyzed the satellite sea-ice observations and COADS meteorological data to examine the causes for these interannual variations. A manuscript, co-authored with S. Honjo and entitled "Atmosphere-Ocean-Ice Interactions in the Okhotsk Sea", has been written based on these analyses.

Meanwhile, we have examined observations of hydrography, tracers, surface wind and air temperature, and satellite sea-ice concentration to study the responses of a coupled ocean-ice system to variations in the atmosphere forcings. It was found that, the ODTL water in the central Okhotsk basin, between 50N and 55.4N in latitude, was considerably warmer and fresher in 1991 than in 1990. Figure 1 shows the potential temperature in these two sections in 1991 and 1990. The ODTL structure is clearly shown in all sections. The difference between 1990 and 1991 are considerable in both surface layer and in the ODTL (Figure 2). The COADS data showed that the northwesterly wind from Siberia was much stronger in the winter of 1990 than in 1991. Therefore, the air temperature was more than 5 deg C colder over most of the basin in January of 1990 than in the same month in 1991. The satellite SSM/I data showed that the sea-ice concentration in the central basin was up to 60(Figure 3). Therefore, the more vigorous convective mixing in 1990 was likely the cause for the observed difference in potential temperature and salinity. The Yang and Honjo (1996) model confirmed our analyses. This indicates that the coupled ocean-ice system in the Okhotsk Sea is very sensitive to variations in the atmosphere, especially in the winter season when convective mixing occurs. It also suggests that a predictive skill can be developed that can be used to infer the oceanographic conditions based on winter atmospheric condition.

Reference

Yang, J. and S. Honjo, 1996: Modeling the near-freezing dichothermal layer in the Sea of Okhotsk and its interannual variations. *Journal of Geophysical Research*, **101**, 16,421-16,433.

Yang, J. and S. Honjo. Atmosphere-Ocean-Ice Interactions in the Okhotsk Sea. Manuscript.


Depth (m)
0
-50
-100
-150
-200
-250
52.0
52.4
52.8
53.2
53.6
54.0
54.4
54.8
55.2
13.0
11.0
9.0
7.0
5.0
3.0
0.00
0.20
-0.20
0.40
-0.40
0.60
-0.60
0.80
-0.80
1.0
-1.20
(a) Eastern Section (1990)
(b) Eastern Section (1991)
(c) Western Section (1990)
(d) Western Section (1991)
Latitude

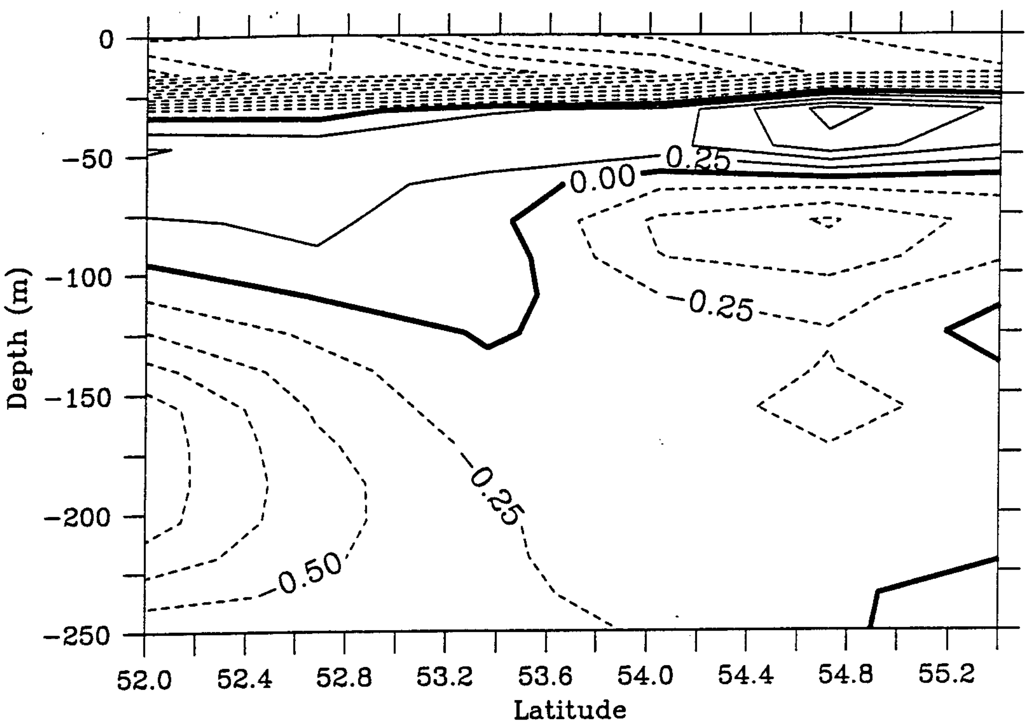


Figure 2(a) Temperature Difference (1991−1990) at 149°15W

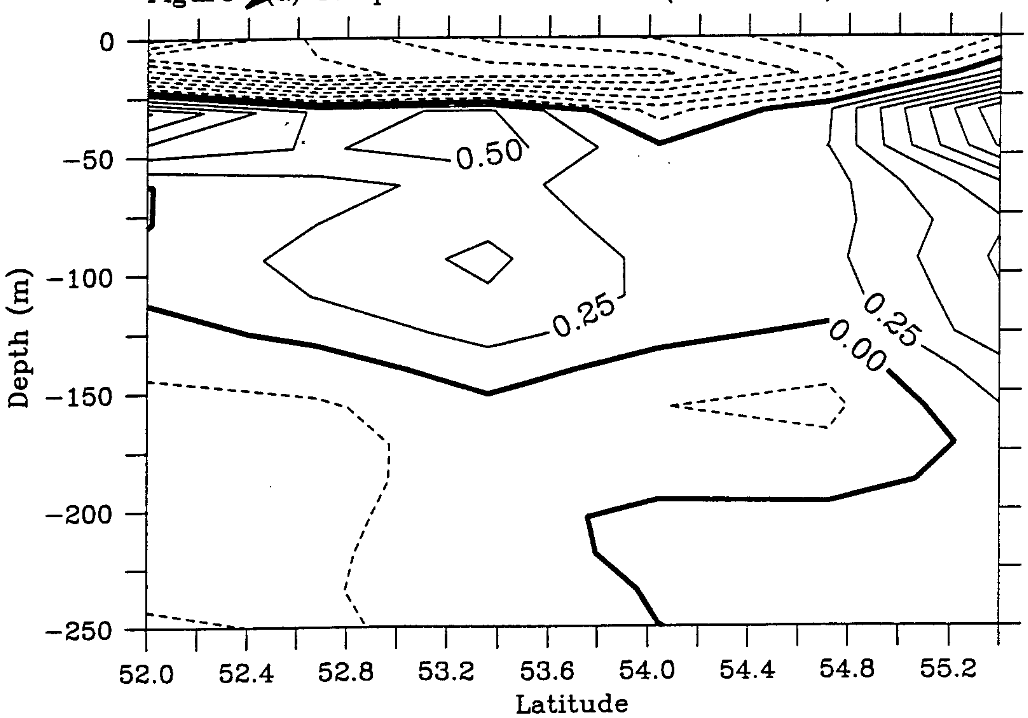
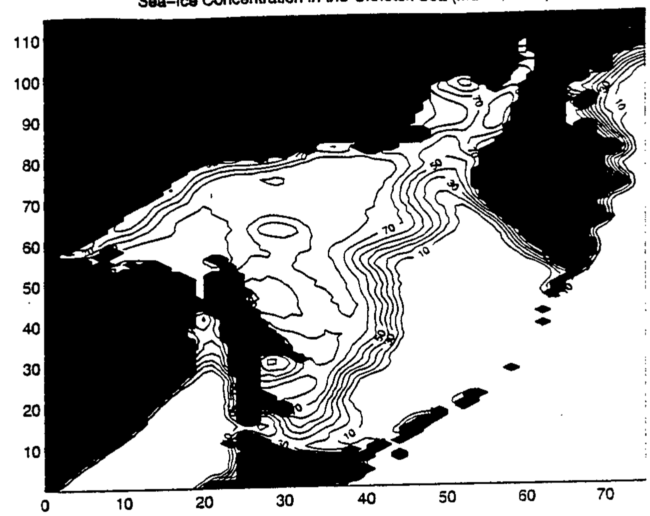
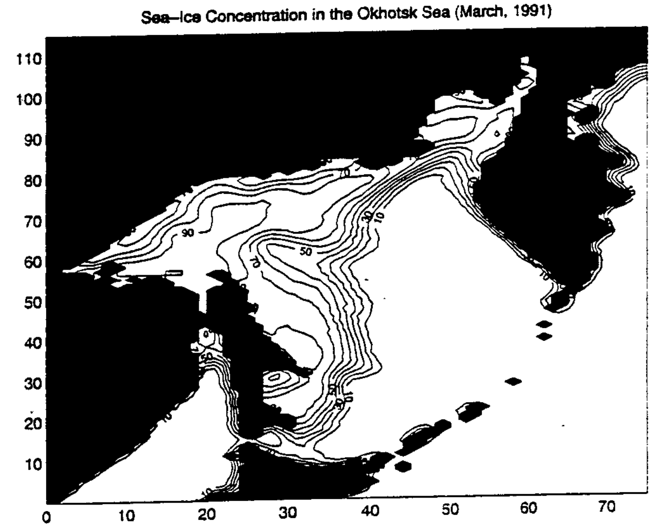


Figure 2(b) Temperature Difference (1991−1990) at 149°50W

Sea–Ice Concentration in the Okhotsk Sea (March, 1990)



Sea–Ice Concentration in the Okhotsk Sea (March, 1991)



Sea–Ice Concentration Difference: 1990–1991 (March)